ASTRONOMICAL OBSERVING CONDITIONS IN THE SOUTHWEST

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Harlan J. Smith

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Harvard College Observatory

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Summary

Analysis of night-time cloud coverage with observatory-site selection in mind was carried out for 20 stations in the Southwestern United States, from synoptic weather map data for the period 1939 to 1946. Monthly and annual averages of the number of clear hours per night were obtained for each station, with probable errors for the annual averages of about five percent.

The results indicate that the best region is that within 100 miles of Yuma, Arizona, where on the average, 6.8 hours per night are clear, with good weather prevailing all year. Eastward, across southern Arizona and New Mexico, winters are superlative but summers are lost almost completely to thunderstorm cloudiness in July and August. Nevada and the northern parts of Arizona and New Mexico have only moderate summer thunderstorm activity, but suffer severely from general cloudiness in winter and spring. Averages in these areas are around 5 hours per night. A peninsula of clearer weather seems to extend up the Rio Grande toward Engle, New Mexico, while West Texas has uniform conditions, averaging 5.5 hours per night.

An "iso-ob" chart of the Southwest was prepared, having contours of equal annual averages of nightly observable time, drawn at intervals of 0.3 hours. Over the regions where the station net is dense, the chart should be a useful guide toward the location of sites.

I. Introduction

Most of the accompanying information on astronomical observing conditions with respect to weather and elevation in the Southwestern part of the United States was prepared in 1947 in connection with the choice of sites for Harvard's meteor stations. After fifteen years of operation of a pair of wide-angle f/4 cameras at the Cambridge and Oak Ridge (now Agassiz), Massachusetts stations of Harvard Observatory, a total of only fifty doubly-photographed meteors had been obtained. Weather conditions were partly responsible for this relatively weak showing. When, in 1946, it became evident that the Super-Schmidt Meteor Cameras, designed by Dr. James G. Baker, would soon be available, it became a matter of major importance to select a location where their enormous potential could be realized fully. Sites within the continental United States were required. We felt no hesitation in restricting our survey to the Southwestern quarter of the country. In a search for material which could guide such a choice, it was found that surprisingly little weather information is available in a form applicable to astronomy. The Harvard study was designed to fill this [illegible] limited degree, and the results obtained were a material factor in the final choice of sites. However, many limitations apply to the work, and the enclosed charts and diagrams should not be used without a clear understanding both of the nature of the problem and the basis for the published results.

When free of other pressures, locations of observatories should be determined by (a) observing conditions, (b) accessibility, and (c) living conditions, in about that order. The latter two categories are by no means negligible in the Southwest, since large areas are inaccessible for all practical purposes, and since existence in others requires special equipment (e.g., the Gila Desert in Arizona).

Observing conditions include as their major elements (a) cloud coverage, (b) transparency, and (c) seeing. Because of the large number of observations required for the reliable determination of seeing and transparency conditions, this information is not available for many locations. In practice, one must rely almost entirely on the records of the few long-established observatories. There seems to be little chance in the near future of improving the situation with regard to these data. However, since all of the cameras used in meteor photography have extremely short focal lengths in comparison with astronomical telescopes, seeing could be neglected completely in the present weather analysis.

Transparency was of somewhat greater [illegible] interest, but the only sources of this type of data are Weather Bureau visibility records. Until recently, these have been made in a relatively haphazard manner; usually in connection with airports. They apply to conditions along the ground and are without consideration of any appreciable vertical thickness of air. In the Southwest they are of even less value, since visibility generally runs well over ten miles - infinite as far as past weather records are concerned - making it impossible to discriminate between good and very good conditions. This situation may be rectified eventually with more general use of various types of precision visibility meters now coming into operation, but for some time this parameter of observing conditions will probably have to remain a matter of secondary local study, after major areas of promising conditions are isolated. (The importance of the transparency factor for solar stations can scarcely be overemphasized.)

Frequency of high winds, rapidity and size of average daily temperature fluctuations, local dust conditions, and depth and weight of winter snows are other more specialized considerations affecting certain types of observatories. These also were almost completely neglected in the Harvard study. As far as the Southwest was concerned, it was felt that cloud coverage was the only sufficiently important weather variable affecting meteor photography. With this explanation, in what follows "observing conditions" or "weather" will be understood to refer to night-time cloud coverage alone unless otherwise specified.

II. Data

At a number of Weather Bureau stations, estimates of percentage of cloudiness are made each hour; the average for the day establishes the cloudiness figure for the day. Over much of the country, where frontal storms predominate, such averages might give a reasonably close approximation to the night-time sky conditions alone, although this procedure would give no idea of the types of cloudiness involved. But beyond this consideration, in the Southwest, where topography, convection, and local disturbances play so large a part in cloud formation and where the passage of a front is something of an event, indiscriminate use of 24-hour averages might prove to be misleading. Consequently, it was decided that an independent average should be made, taking into account none but observations made at night.

The only source of such observations available in Boston proved to be a file of synoptic weather maps*, upon which are plotted, four times a day, the complete weather data for hundreds of stations over the country. Twenty stations were selected on the basis of the regularity of their reports, and in terms of their distribution, in order to obtain a reasonable coverage of the Southwest. Western Texas, Southern New Mexico, all of Arizona, Southern Nevada, and parts of Southern California were included. The specific stations are given in Table I, and their locations are shown on Figure 1.

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* Kindly made available by the Massachusetts Institute of Technology Weather Station.

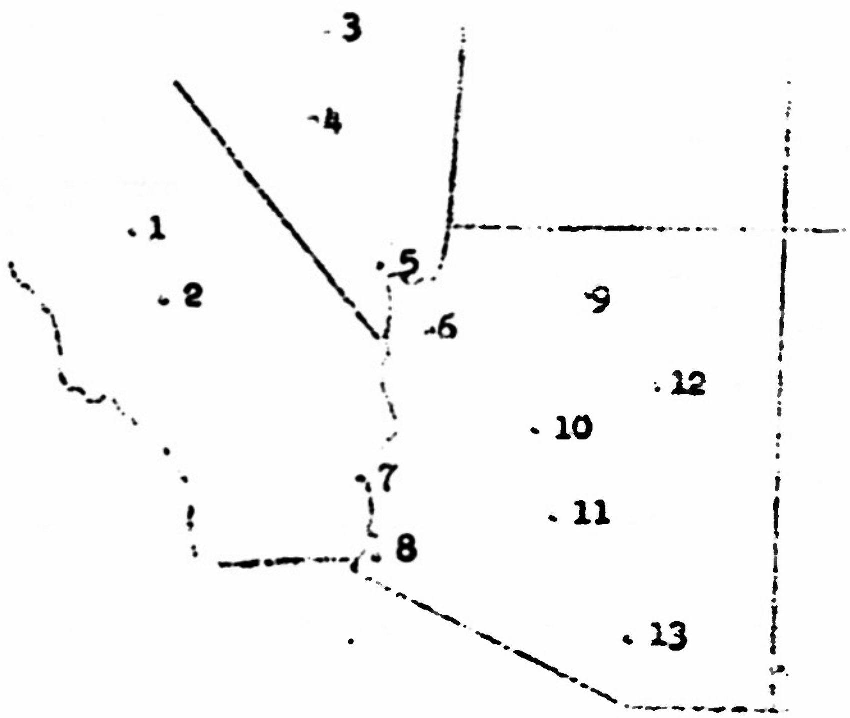
TABLE I

Weather Stations For Which Cloud Coverag

1.	Fresno, California	12.
2.	Bakersfield, California	13.
3.	Austin, Nevada	14.
4.	Tonapah, Nevada	15.
5.	Las Vegas, Nevada	16.
6.	Kingman, Arizona	17.
7.	Blythe, California	18.
8.	Yuma, Arizona	19.
9.	Grand Canyon, Arizona	20.
10.	Prescott, Arizona	(21.)
11.	Phoenix, Arizona	

FIGURE 1

Outline Map Showing Location Of St



* Numbers refer to those given in the

taken from the two
for which were made
, covering a sampling
file of weather maps
ime required to take
over the full seven-
mpling of 3,000 maps
observations per
n all, 39 months of
J.T. observations were
te observations avail-

included type and
ions (when given), and
was classified, by
onthly averages were
nd one-tenth of high
ervable," (although
h some success even

lear" sky still required
picture of observable
s twice as many hours of
s from the American Nau-
the appropriate correction

being made as a function of latitude. The result gave the average number of observable hours per night (between astronomical twilights)* for each month at each station. This information is available in both tabular (Table II) and graphical form (Figures 2 through 10). Finally, for each station, the direct mean of the monthly values gives the annual average.

(Text continues on Page 12.)

* In these latitudes there are about 3200 hours of astronomically-dark sky per year, or on the average, 8.8 hours/night.

TABLE II

Monthly Averages of Observable Hours Per Night for Stations

	Fresno, Cal.	Bakersfield, Cal.	Tonapah, Nev.	Austin, Nev.	Kingman, Ariz.	Las Vegas, Nev.	Winslow, Ariz.
Jan.	2.1	3.6	6.6	6.0	4.6	5.7	6.6
Feb.	2.7	5.3	5.5	5.2	5.3	4.9	5.4
Mar.	4.2	3.6	6.0	5.0	5.5	5.2	6.4
Apr.	4.7	6.4	4.7	4.9	4.3	4.5	5.5
May	3.6	3.6	3.4	2.9	4.5	3.3	5.0
June	3.7	4.9	3.6	3.0	4.7	4.5	4.6
July	4.7	4.6	3.6	3.6	3.4	2.9	3.7
Aug.	5.9	---	5.4	4.5	4.9	4.2	4.4
Sept.	8.1	7.7	7.3	7.5	6.7	6.9	6.3
Oct.	6.6	6.2	7.0	7.3	6.8	6.6	6.9
Nov.	2.8	5.6	7.1	5.9	7.0	7.1	7.9
Dec.	1.6	4.2	6.3	4.5	5.5	5.7	6.1
Average	4.2	5.1	5.5	5.0	5.3	5.1	5.7
No. of Obser.	151[illegible]	250	1754	1216	1125	1716	1144

TABLE II (con't)

	Grand Canyon, Arizona	Prescott, Ariz.	Phoenix, Ariz.	Tucson, Ariz.	Rodeo, N.Mex.	El Paso, Texas	Engle, N.Mex.
Jan.	5.7	7.4	6.4	6.5	7.3	6.4	8.7
Feb.	4.8	4.4	4.8	5.6	7.9	5.6	7.2
Mar.	5.7	6.4	6.0	5.7	7.1	6.3	7.5
Apr.	4.7	6.0	5.5	5.8	6.3	6.0	5.8
May	5.0	6.0	5.0	5.6	5.5	4.9	5.5
June	4.9	5.4	5.0	5.0	5.4	4.7	5.8
July	4.4	5.0	3.7	2.5	2.2	2.7	2.3
Aug.	5.1	6.0	4.3	3.0	2.5	3.8	4.2
Sept.	6.8	7.5	6.5	5.6	5.7	5.1	6.4
Oct.	7.3	7.3	7.6	7.0	6.4	6.9	6.7
Nov.	7.8	8.1	7.7	7.7	7.0	7.2	8.9
Dec.	5.8	7.5	6.5	6.8	7.5	7.0	8.0
Average	5.7	6.4	5.8	5.6	5.9	5.6	6.4
No. of Obser.	1014	638	1272	1302	1020	1316	614

TABLE II (con't)

	Wink, Texas	Alpine, Texas	Big Bend, Texas	Carrizozo, N.Mex.	White Sands, N.Mex.	Blythe, Cal.	Yuma, Ariz.
Jan.	6.5	7.6	6.8	7.6	5.6	7.2	7.4
Feb.	5.7	6.8	4.4	8.1	6.4	7.0	7.6
Mar.	6.0	5.6	7.3	5.4	5.6	6.9	6.8
Apr.	5.9	6.7	7.0	5.4	5.0	5.4	6.5
May	3.7	5.1	6.6	4.0	4.8	5.2	5.3
June	3.8	3.8	5.0	3.3	3.6	5.2	5.8
July	3.1	4.2	4.1	3.4	2.0	4.1	5.0
Aug.	4.3	3.6	5.1	3.4	3.0	4.7	5.8
Sept.	4.9	5.4	5.1	4.6	5.0	7.5	7.3
Oct.	6.3	5.6	7.7	7.1	6.0	7.6	7.5
Nov.	7.3	6.8	7.3	7.2	7.8	9.3	8.7
Dec.	6.5	7.3	7.1	4.3	5.7	7.0	7.8
Average	5.3	5.7	6.1	5.3	5.1	6.4	6.8
No. of Obser.	1160	649	798	322	1222	309	1437

Fig. 2

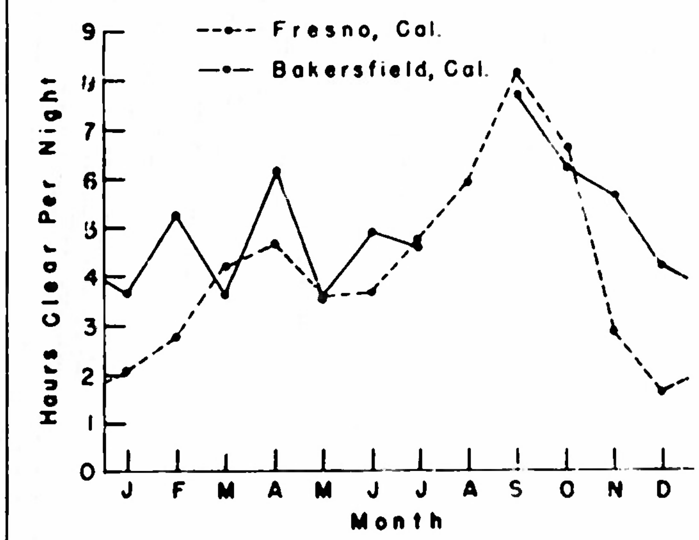


Fig. 3

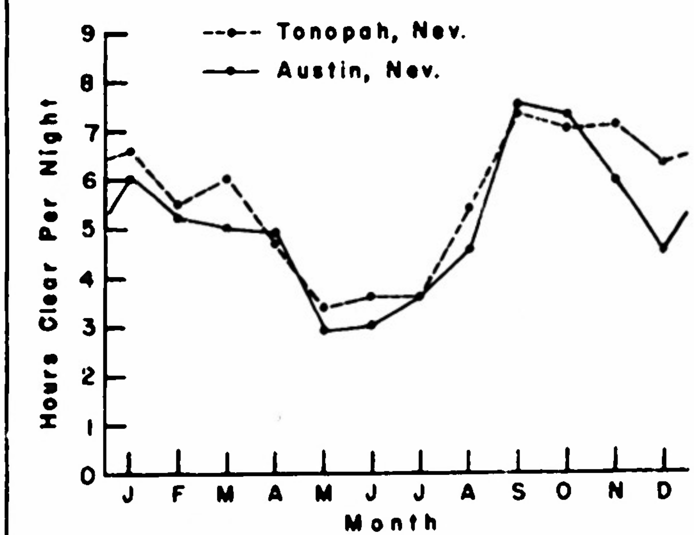


Fig. 4

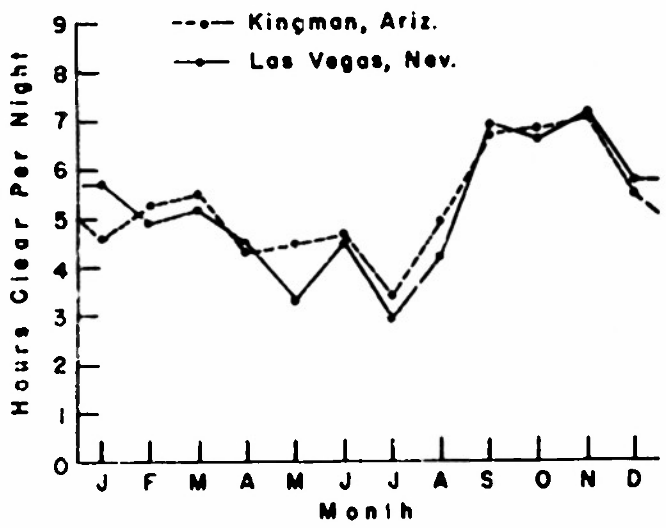


Fig 5

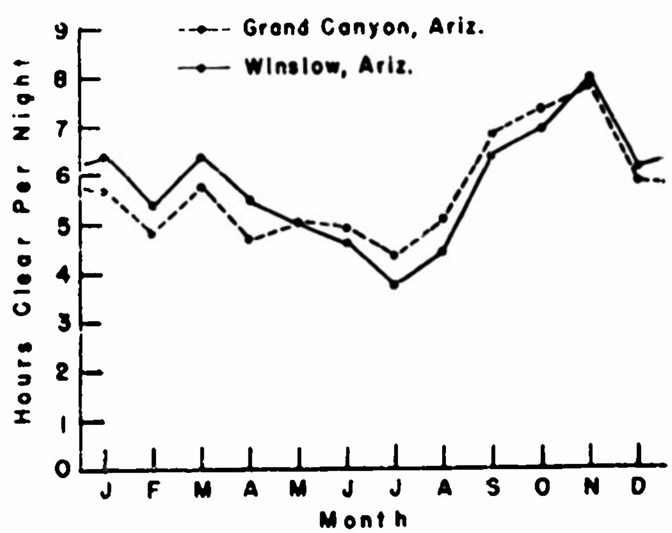


Fig. 6

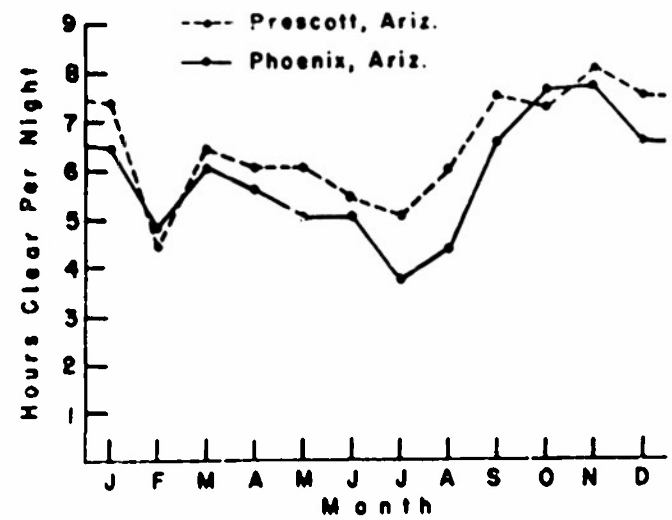


Fig. 7

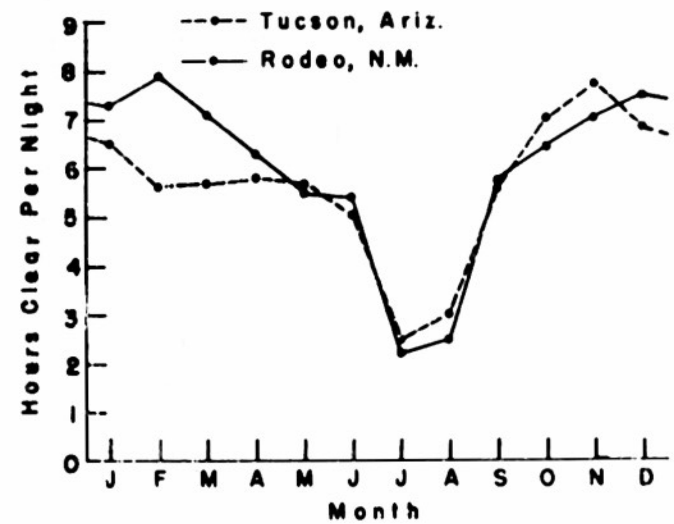


Fig. 8

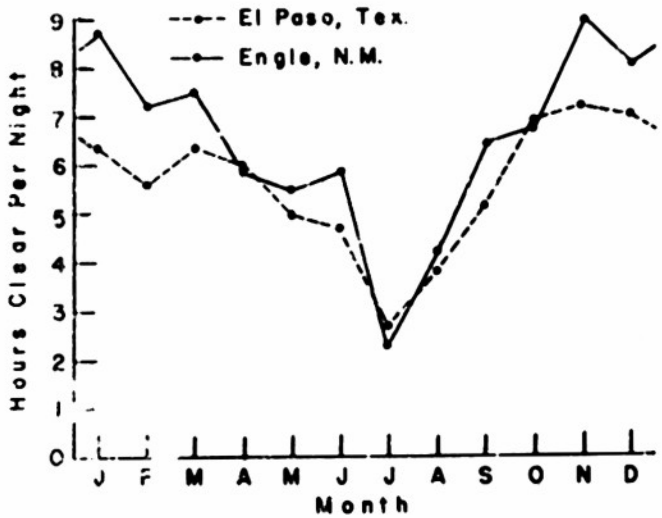


Fig. 9

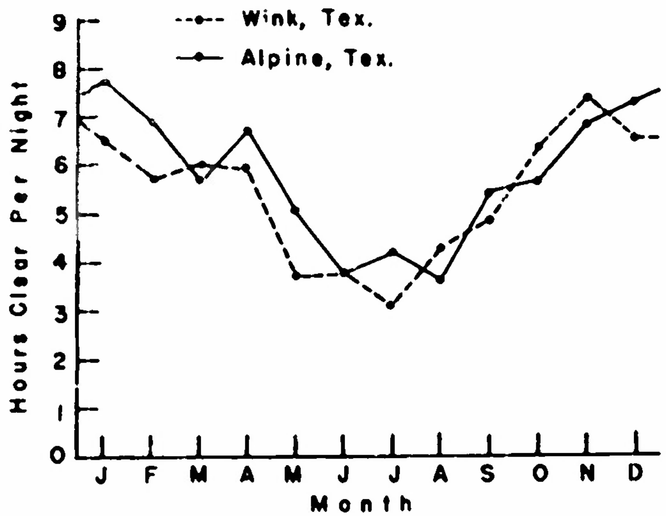
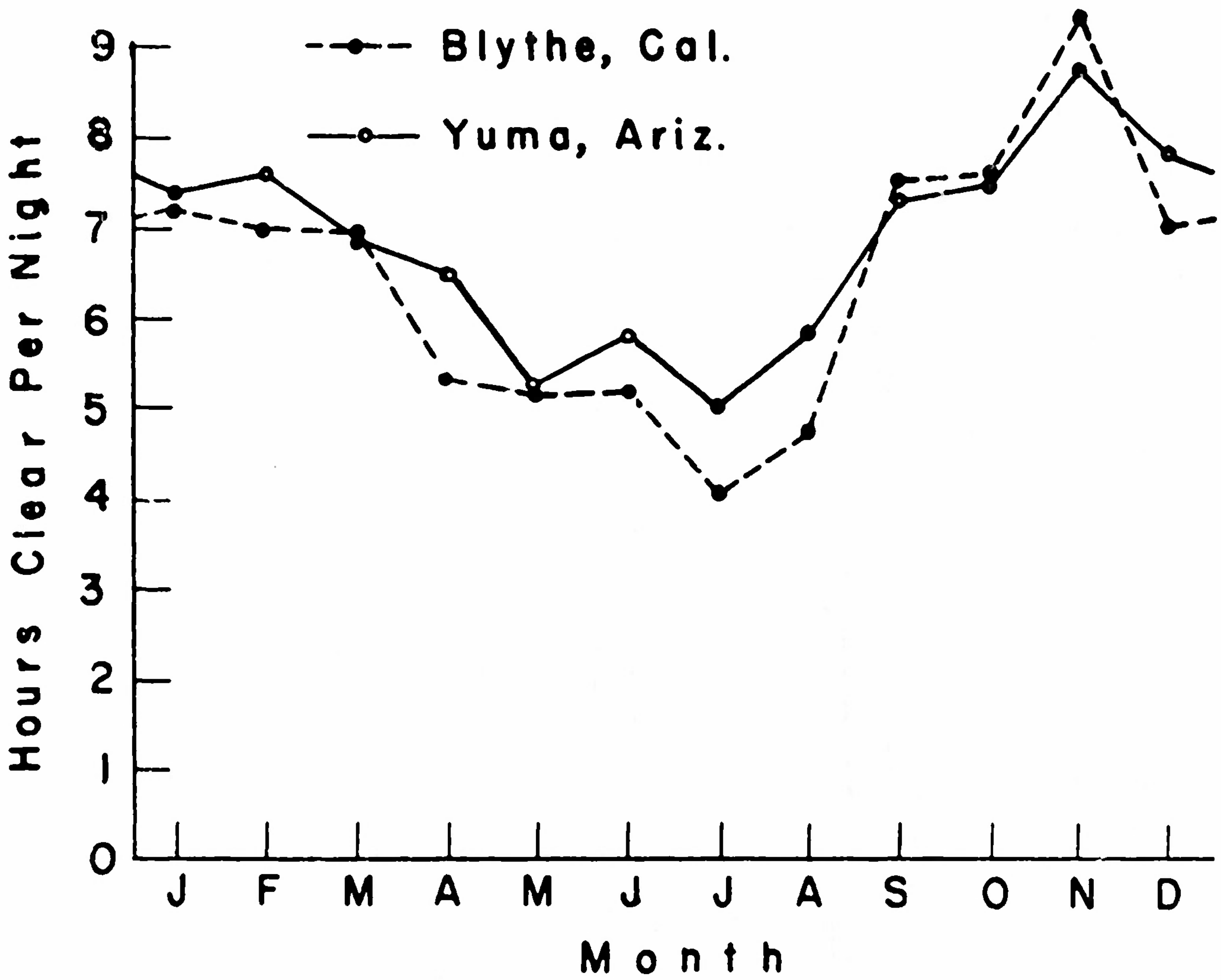


Fig. 10


Blythe, Cal.
Yuma, Ariz.
Hours Clear Per Night
0
1
2
3
4
5
6
7
8
9
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F
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A
M
J
J
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S
O
N
D
Month

III. Results

Consideration of the station graphs leads to a few general conclusions. In particular, five regions, rather distinct in their pattern of night-time cloud coverage, stand out:

a) California, west of the Sierras (Figure 2):
This area suffers from the tendency of onshore winds in the winter to produce clouds and rain. It is unfortunate that the original selection of stations did not include several more in Southern California. However, use of Mt. Wilson statistics[1] and published discussions of weather in connection with the selection of the Palomar site indicates that there is a substantial improvement as one goes from north to south in this area.

b) Nevada, Utah, and Northern Arizona (Figures 3, 4, 5, and 6):
This region, in the lee of the Sierras, is characterized by fairly good weather throughout the year. There is some winter frontal storm activity and in the summer thunderstorms are frequent. With localized exceptions, one finds improved conditions to the south

1. 1930, Mt. Wilson Annual Report of the Director indicates that during the period 1911 to 1930, the 60" telescope was used 63% of the night hours. This reduces to about 5.5 hours/night on our system.

and west. Prescott in the southwest corner of this region proved to be one of the better locations considered.

c) Southern New Mexico, Southeastern Arizona (Figures 7 and 8):
Although sufficiently far south to be relatively free of the winter frontal storm activity so characteristic of most of the United States, this semi-arid region has intense summer thunderstorm activity. Violently convective clouds, building up almost every afternoon in July and August, leave residues of heavy middle and high clouds which frequently do not dissipate until the next morning. Although these storms are a general phenomenon over the entire Southwest, their greatest frequency occurs in a region centered around the southern New Mexico and Arizona borders, with intensity diminishing considerably to the east, north, and west.

d) West Texas (Figure 9):
West Texas represents a climatological compromise between a variety of factors. It is far enough west to avoid most of the moist circulation from the Gulf of Mexico, far enough south to have only occasional frontal storm passage, and is east of the most concentrated thunderstorm activity. It is not

conspicuously shielded by any immediately adjacent major mountain masses. The result appears as an extremely uniform percentage of cloud cover throughout the year. Although individual months often deviate widely, on the average the various seasonal types of disturbances integrate smoothly over a period of years.

e) Southwestern Arizona, Southeastern California (Figure 10):
Without question, this region, centered on Yuma, Arizona, has the least night-time cloud coverage of any section of the United States. It is well-protected from Pacific moisture by the masses of California mountains, is too far south for a high incidence of winter storms, and is sufficiently arid to escape serious thunderstorm activity in the summer.

The individual monthly values for each station seem quite adequate to differentiate the gross seasonal weather patterns for the various regions, as has been emphasized in the grouping of graphs by geographically-contiguous pairs (Figures 2 through 10).

The comparative stability of the annual averages for the different stations gives them an additional utility. With their aid, it became possible to attempt a generalization of these data, limited - unfortunately - as they are. By plotting all twenty-one

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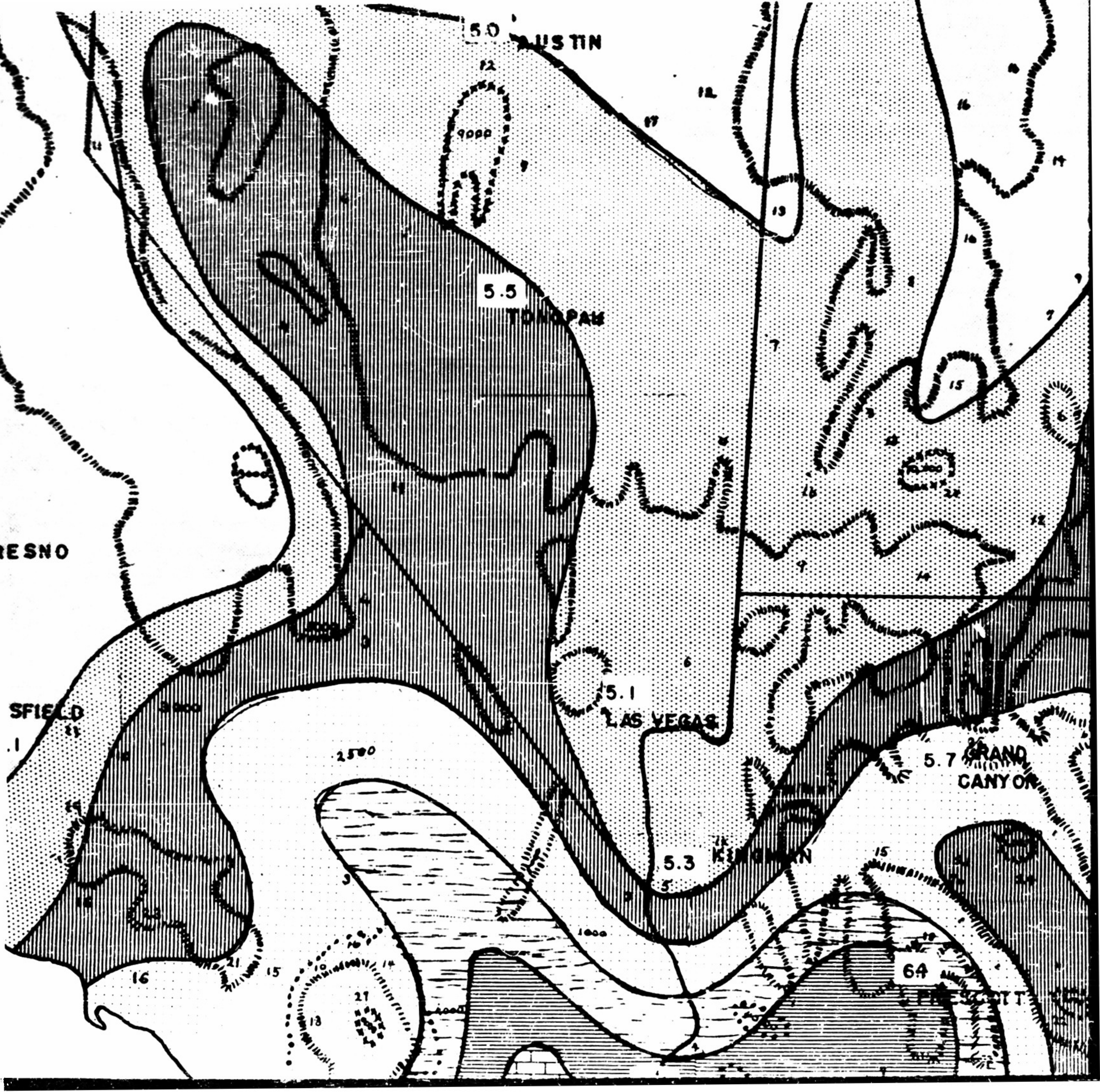
stations on a geographical map
number of observing hours per n
reasonable to imagine "iso-obs,
hours, over the entire Southwes
nothing else to guide the conto
even major variations proved di
Southwest weather proved usefu
surrounding regions, rainfall i
tion. Cloudiness, in turn, has
rainfall. Thus, if contours of
the map, and if many-year rainfa
considerable density over the ma
locally in conjunction with the
observing hours were studied in d
tours with greater clarity and de
case.

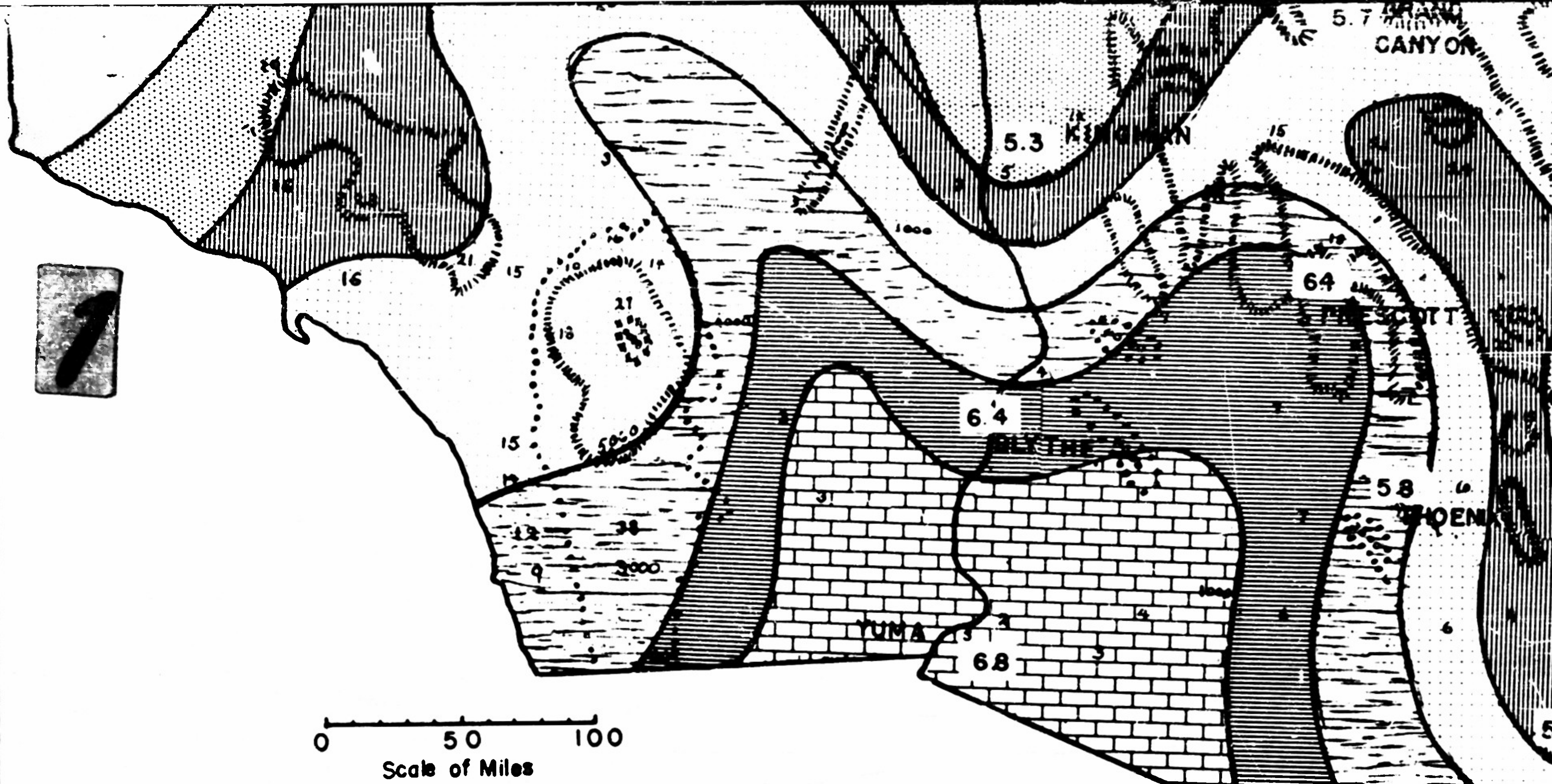
In this fashion, Figure 11
at intervals equal to 0.3 of an h
an individual station's determina
the number of observable hours pe
from the Yuma center. When the
Utah, and Northern New Mexico), t
as distinctly sketchy.

Irwin[2] has recently publis

2. Science, 115, 223, 1952. (
Ibid., 116, 572, 1952.)


5.0
AUSTIN
5.5
TONOPAH
RESNO
SFIELD
5.1
LAS VEGAS
5.7
GRAND
CANYON
5.3
64

1



EXPLANATION OF SYMBOLS USED ON ACCOMPANYING MAP

6.5 Average number of observable hours per night throughout the year, corrected for latitude and seasonal day-night lengths

12 Mean annual rainfall (1912 data used)

5000 foot contour line

Significant elevations above 5000 feet

Significant elevations below 5000 feet

Region having more than 6.5 hours of good observing weather per night

Region having between 6.2 and 6.5 good hours per night

Region having between 5.9 and 6.2 good hours per night

Region having between 5.6 and 5.9 good hours per night

Region having between 5.3 and 5.6 good hours per night

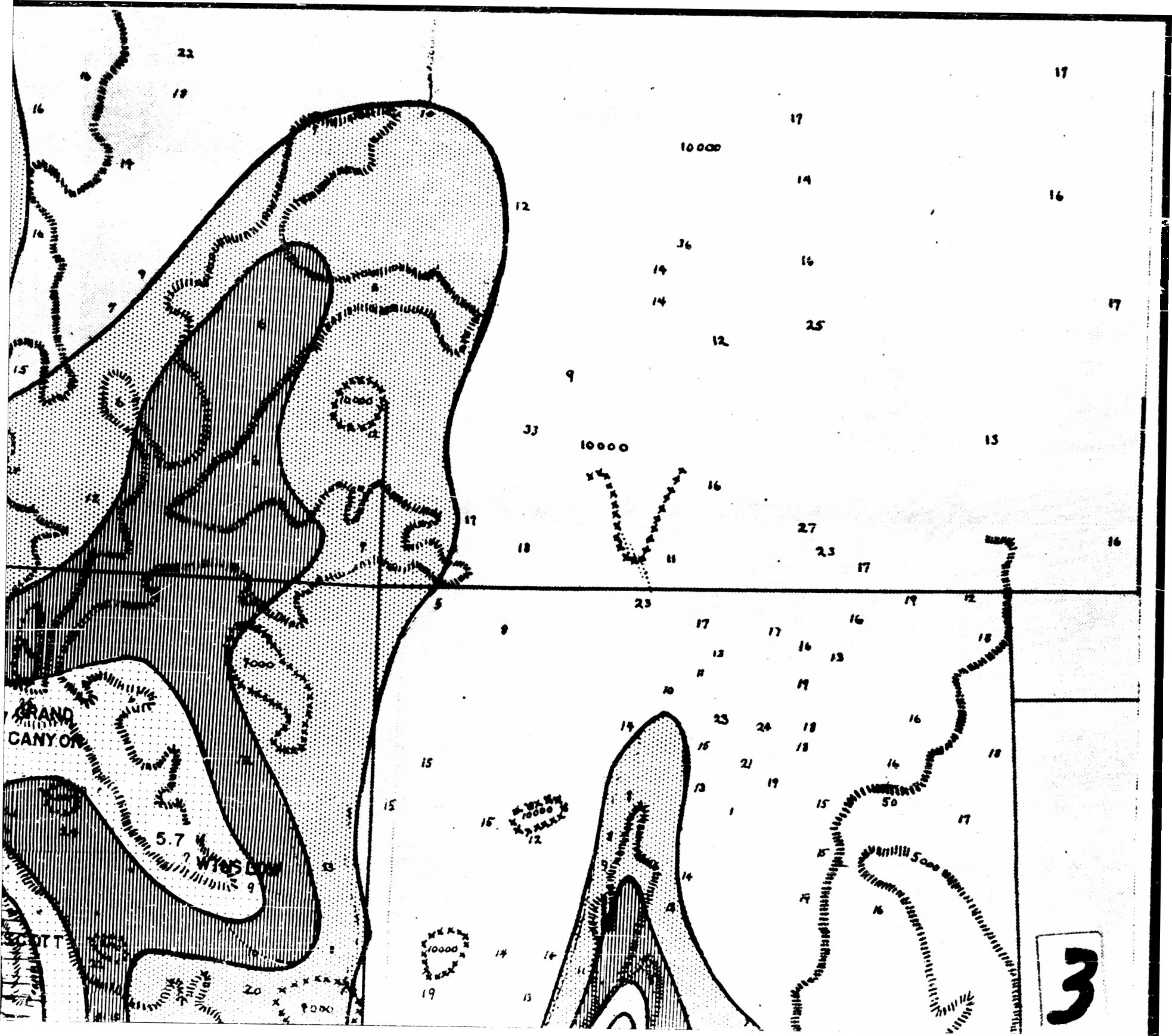
Region having between 5.0 and 5.3 good hours per night

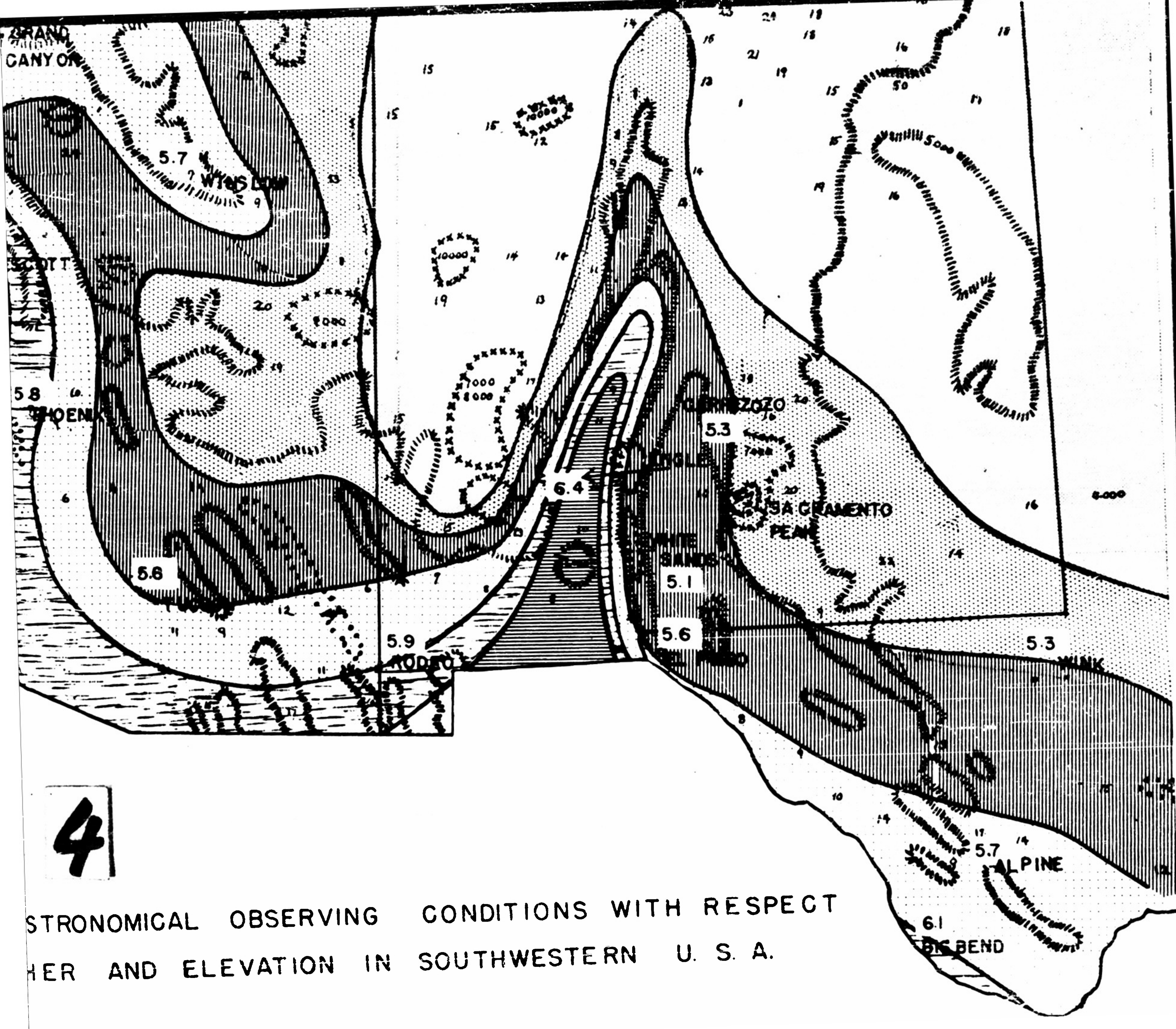
Region having less than 5.0 hours of good observing weather per night

2

CHART OF ASTRONOMIC

TO WEATHER AND


GRAND
CANYON
5.7
WINSLOW
3



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STRONOMICAL OBSERVING CONDITIONS WITH RESPECT
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but it is based upon Weather Bureau 24-hour clear-day statistics, rather than on night-time data alone. (It should be noted that, for the Weather Bureau, a "clear" day is one with less than .3 clouds.) The advantage of his procedure lies in the far larger number of years for which consistent data are available. Although more heavily smoothed, his chart agrees in broad outline with Figure 11.

It is also of interest to compare the observing conditions at Boston with these results. A compilation of telescope records at the Agassiz Station of Harvard Observatory, covering the period 1933-1943, prepared by A. A. Hoag, indicates that about 2.9 hours/night are "clear" in approximately the critical sense in which we have defined the word.

IV. Checks and Comparisons - Internal and External

(1) If the analysis is reliable, stations in the same general region should show similar monthly characteristics and annual averages. Inspection of the figures shows that this is indeed the case.

(2) Another check is the self-consistency of data at any station between the midnight and morning observations. The file of weather maps used provided 1230 U.T. observations from 1939 through 1944, and 0630 U.T. observations from 1943 through 1946. Thus, accumulation of data for each of these observing times actually represents a different set of years, and provides a broader sampling than would have been the case if the two sets had always been concurrent.

The average of the absolute differences shown by each station between annual means of 0630 U.T. and 1230 U.T. observations is 6%. Nearly all of these differences are in the sense that the midnight observations show better conditions than the dawn. This algebraic mean is 4%. One might expect, a priori, to find an improvement near dawn, because of the tendency of convective-type clouds and their frequent residue of cirrus and altostratus to dissipate during the night. It is possible that the anomalous effect in our data is produced by the phenomenon of "sunrise cirrus."* It is equally possible that the necessity of comparing midnight and dawn data from different years can explain the sense of the residual.

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* The experience of both authors in the U. S. Army Air Corps Weather Service was that night-time estimates of cloudiness might be somewhat in error for several reasons. The primary effect, referred to above as "sunrise cirrus," results from the fact that high, thin, or distant clouds are difficult to see at night, but become especially visible at daybreak (this, unfortunately, is not counterbalanced by the not-infrequent predilection of weather observers to record the Milky Way as cirrus). In support of this contention, our data show that the apparently better conditions at midnight result almost entirely from a relative absence of small amounts (0.2 to 0.3) of cirrus and not of any other cloud condition.

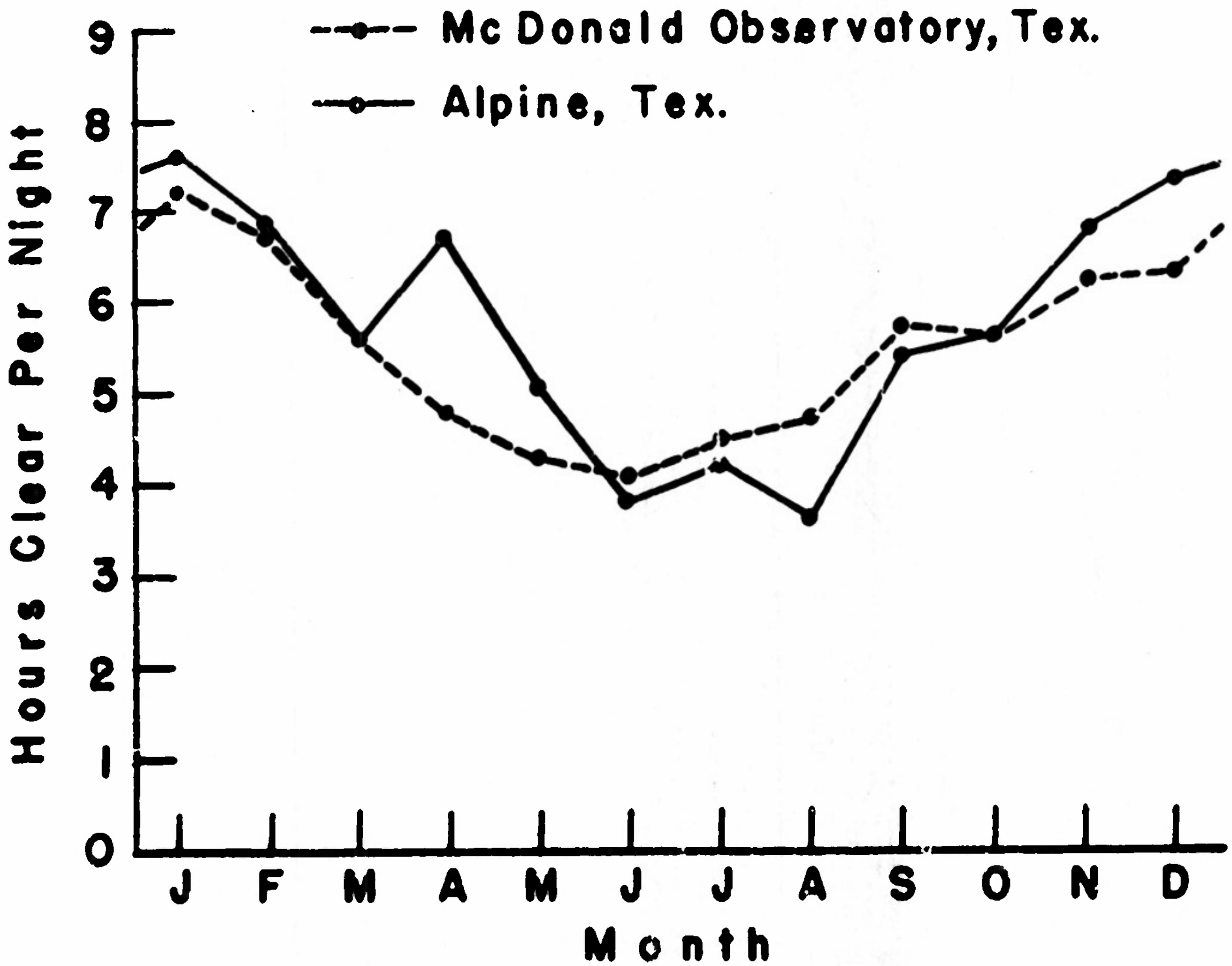
(3) McDonald Observatory has kindly supplied a record of the monthly number of observing hours for a seven-year period coinciding approximately with that of our study. This information is plotted in Figure 12, along with the corresponding data obtained from the synoptic maps for the station Alpine, Texas, which is 42 miles southwest of the Observatory and 2,200 feet lower in elevation. The calculated local yearly average of observing hours at Alpine was 5.8/hours/night. The average actually observed at McDonald was 5.5 hours/night. The agreement of the two curves in shape is good. (Note the more widely divergent shape of any other station graph.)

Individual calculated monthly averages for Alpine differ from the McDonald records by an average of 7%. The primary reasons for these minor discrepancies are to be found in the difference of location and elevation, and in the fact that too few Alpine observations were available to effect a smoothing (on a monthly basis) comparable with that at McDonald. It should also be pointed out that the McDonald data were derived from summaries of telescope operating time, which does not necessarily bear a one-to-one correspondence with "observable" sky, as we define it.

(4) A variety of checks verify certain specific conclusions.

Those responsible for selecting McDonald's site in West Texas observed from climatological data that they should avoid El Paso because of its greater number of rainy days; this showed up in the detailed analysis in terms of ElPaso's location at the eastern end of the severe summer thunderstorm belt.

Fig. 12


McDonald Observatory, Tex.
Alpine, Tex.
Hours Clear Per Night
0
1
2
3
4
5
6
7
8
9
J
F
M
A
M
J
J
A
S
O
N
D
Month

E. F. Carpenter reported[3] excellent astronomical conditions in Southern Arizona except during July and August; and this is perhaps the clearest single conclusion that can be drawn from the charts. He also mentioned, and the graphs verify, a diminution of this thunderstorm activity in the northern part of the state, but a progressive worsening of winter conditions at the same time.

The Smithsonian Institute has tried several Southwestern locations, while searching for suitable sites at which to measure the solar constant. Around 1920, a station was established at Harqua Hala, Arizona (33°48'N, 113°20'W; elev. 5600'). Although solar constant measures could be made on nearly 80% of the days, the site was abandoned after 5 years. Three reasons were given: (a) isolation and discomfort - five miles from a road, uncertain water supply, heat; (b) spring and summer haze, spring cirrus clouds; and (c) high winds and violent thunderstorms in midsummer. As haze is an especially serious obstacle to solar constant work, it is likely that this condition is over-reported and would have little effect on most kinds of night observing. The thunderstorms are certainly present, although to a lesser extent than in southeastern Arizona. Table Mountain, California (34°22'N, 117°41'W; elev. 7500'), overlooking the Mojave Desert, was found to be a more livable site and to have slightly less haze,

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3. Private communication, April, 1947.

but suffered from poor winter months. After further investigation, Burro Mountain, New Mexico (32°40'N, 108°33'W; elev. 8000') was selected. Here the thunderstorm trouble again partially blocked work in July and August, but winter conditions were found to be superb. All three sites seem comparable in total number of usable days. The above conclusions agree well with the iso-ob chart and station graphs. In particular, it should be noted that Engle, the nearest of our stations to Burro Mountain, shows (with Yuma) the best winter weather to be found in the Southwest.

Finally, E. Öpik has pro ded[4] data from his 1931-1933 meteor expedition to Flagstaff. A comparison of the number of nights per month on which he observed coincides well with the predicted number as derived here from weather maps.

(5) A single station completely independent of all the rest of the data on the iso-ob chart is provided by White Sands Proving Ground, 50 miles north-northeast of El Paso. The cloud coverage data for this station were taken from ground observations accompanying radiosonde flight records, made once or twice a night, during the years 1947 to 1952. The times of observation do not coincide with the regular 0630 and 1230 U.T. observations of the Weather Bureau, and it should be noticed that there is no overlap with the years covered in the rest of the survey. By reducing the White Sands records in much the same way as was done with the synoptic data, a figure of 5.1 hours/night was obtained, as compared

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4. Private communication, April, 1948.

with the 5.5 hours which the iso-ob chart would predict for this location (see Figure 11 and Table II). The difference is 8%, about twice the error which the annual fluctuations in the rest of the data would lead us to expect. Most of the difference presumably arises from a long-term statistical fluctuation affecting the two sets of years through which the data were taken.

That such fluctuations exist is known, but the use of them to explain this discrepancy without supporting observations is hardly satisfactory. The difference might well be in local fluctuations or in the reduction of White Sands data which, although comparable to the synoptic data, do not represent an identical set. But by utilizing some information obtained at the Sacramento Peak Upper Atmospheric Station (50 miles northeast of White Sands), an independent determination of the reliability of some of the White Sands data can be made. The Sacramento Peak cloud coverage information results from the measures of night-long photographs taken of the north polar region with a fixed camera. Clouds are then recorded as a diminution of intensity in the star trails. One tends to have more faith in this observing technique than in visual observations.

The percent of clear skies determined by the Pole Star Records are available for the period March, 1951, to March, 1952. The average number of observable hours per night for this period correspond almost exactly to the White Sands figure for the same period. The general shapes of the two curves are similar. The mean monthly deviation is 11%. The agreement is rather better than one would expect, considering the difference in height between the two stations. Although covering but a single year of the observations, such agreement makes the long-term statistical fluctuation seem a more plausible explanation.

(6) Data for 12 stations for the months of December and January were averaged for each year separately through four consecutive years. These averages were compared with the overall means. An average deviation of ±8% was found, with 25% to 30% the extreme. As remarked above, similar data (for all 12 months, however,) were taken from White Sands Proving Ground records covering the years 1947 to 1951. For this single station, the average deviation of any individual month from the five-year mean was 9%. Individual yearly figures differed from the final adopted mean by an average of 4%. If the months were entirely independent in their fluctuations from year to year, the annual deviations would be less than the monthly by a factor of $\left(\frac{1}{\sqrt{12}}.\right)$ Since this is not the case, it appears that there is a certain amount of coupling between months in good and bad seasons - a not-unexpected result, especially in view of (5) above.

It is difficult to assign meaningful probable errors to the differences of monthly and annual figures between the various stations. Certain systematic effects are probably present, placing the data for any given individual station on a slightly different system from the others. Such effects can only be removed by the use of much longer runs of observations and a far denser station network. However, from the rather smooth way in which the annual figures vary across the iso-ob chart, and from the degree of fit of the independent McDonald, White Sands, and Mt. Wilson data, it seems that a conservative estimate of the relative precision of the monthly and annual points is of the order of the annual deviations from the mean at any single station.

The "probable errors" of the monthly figures in Table II may therefore be estimated as approximately 0.7 hr., while those of the annual averages are about 0.3 hr.

V. Conclusion

It is our conclusion that real and significant differences in night-time cloud coverage exist over the Southwestern states, but that this study must be taken as only the beginning of a proper analysis of the astronomical weather problem in the Southwest. Even if all of the station points are accurate within their estimated errors, they are so few in number as to provide but the first approximation to the correct picture, while the device of supplementing them with elevation and rainfall statistics is one to be abandoned as soon as possible.

For many astronomical purposes (e.g., spectroscopy, positional astronomy, meteor observation), the monthly and annual figures given here should be conservative in terms of potential operable time. For photoelectric work, however, because of our inclusion of 0.1 cirrus as "clear,"* and because of the desirability of reasonably extended stretches of perfect sky, the figures given should be reduced by a significant amount - probably by 10 to 20%.

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* (See next page.)

Finally, we must mention again that there are many other variables equally important astronomically which have not been considered here, partly because they were relatively unimportant to meteor work and partly because of the sheer difficulty of getting reliable data on them. The primary utility of this study will lie in blocking out areas in which to search for reasonable sites satisfying other considerations as well, and in providing a known rather than an estimated figure for the loss in observable time resulting when sites outside the optimum zones are selected or operated for other reasons, as they will generally continue to be.

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* The percent of otherwise scattered cirrus (more than .1) was recorded separately and this provides enough data for us to be able to say with some confidence that the annual average of .1 cirrus is fairly uniform over the Southwest to the amount of about 5%, with increases probable in the thunderstorm belt and toward the Northwest. This amount, as a minimum, must thus be subtracted from Table II to convert it into photoelectric hours.